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NATIONAL BUREAU OF STANDARDS REPORT

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QUARTERLY REPORT

ON

EVALUATION OF REFRACTORY QUALITIES OF

CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK,

MAINTENANCE APRONS, AND RUNWAYS

by

W. L. Pendergast, E. C. Tuma, L. E. Mong

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Refractories Section
Mineral Products Division

Sponsored by

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Dr. Samuel Zerfoss
Chief, Refractories Section

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1. INTRODUCTION

This phase of the project includes the determination of the cause or causes of failure that occur in concrete aprons and runways exposed to jet exhaust gases. A combustion chamber that delivers hot gases at velocities and temperatures approximating those of field conditions is being used. The approach includes instrumentation of the concrete test panels to determine the heat gradients and stresses set up during flame impingement at several locations on the test area and at varying depths below the surface.

2. ACTIVITIES

2.1 X-ray Examination of Neat Cements

The drying and heating of samples, of the neat cements, portland, Lumnite, and Alcoa taken from bomb, after a heating cycle (not exposed to mercury) has been continued. Samples for X-ray analysis has been prepared. Personnel has not been available for making X-ray examination.

2.2 Water in Concrete During Curing and Drying

The drying of the set of five tiles, 3" x 3" by four inches, in depth, described in NBS Report 5855 has been continued. The data obtained is given in Figure 1. In the designation P-B-B, P-B-T etc, the P refers to portland cement, the B crushed brick aggregate, and the final letter refers to the fabricator; T_S signifies that the top one and one-half inches of tile was sawed off after seven days fog-room curing and the remaining four inch

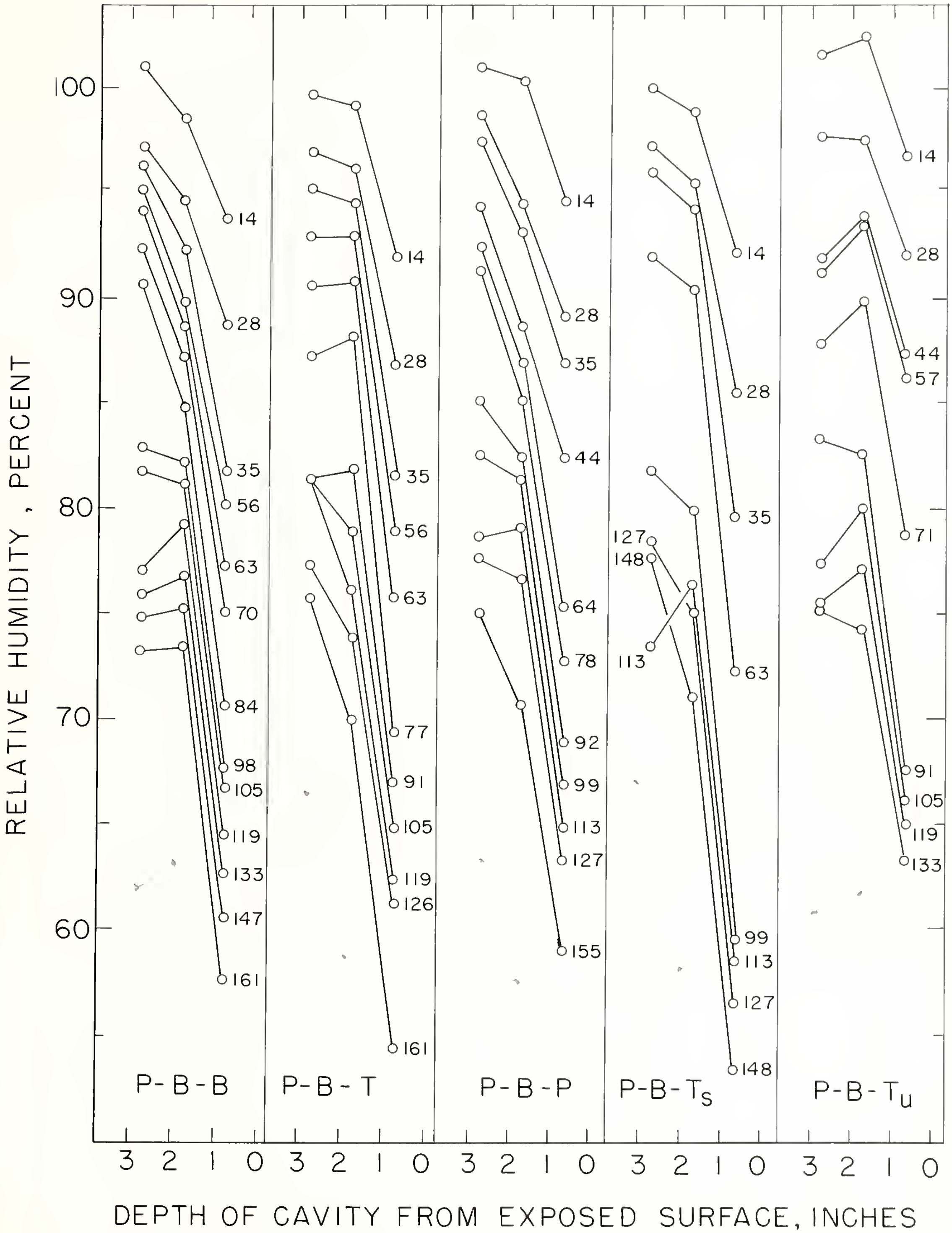

FIGURE 1 RELATIVE HUMIDITY AT THREE DEPTHS FROM EXPOSED DRYING FACE. TILES P-B-B, P-B-T, AND P-B-P MADE BY THREE INDIVIDUALS, P-B-T_s WAS CAST AND EXCESS ONE AND ONE HALF INCH AT TOP SAWED OFF, P-B-T_u WAS INVERTED.

depth was retained; Tu signifies that the tile was inverted and the bottom, as cast, was exposed to the curing and drying atmosphere. The number on the curves refer to the drying time, in days.

Figure 1 shows that the relative humidity distribution at the three depths from the drying face is characteristic to each tile. The difference in relative humidity between any two adjacent depths apparently depends on the concentration of water at a given time and the water permeability of the concrete separating the two depths. As shown in the early stages of drying it is possible to place a concrete with nearly equal permeability as indicated for specimens P-B-B, and P-B-P. That concrete may be formed less permeable at the bottom of the tile as shown by specimen P-B-T. On the other hand this effect may be reversed by exposing the bottom of the tile as cast to curing and drying atmosphere as shown by curves for P-B-Tu. Discarding the top portion, which is apt to contain a larger percentage of fines, cement, and mixing water, results in a tile having relatively larger permeability throughout.

Drying during the early stages caused an increase in permeability as indicated by the large difference between the relative humidity at the cavity nearest the drying face and at the middle cavity. For these cavities the water is lost before the permeability is reduced by a slowly continuing hydration of the cement that occurs in the concrete between the middle and lower cavities. This curing, continued hydration, in the presence of the higher concentration of water near the

bottom of the tile apparently temporarily seals the concrete at drying times greater than 70 days and at relative humidities between 74 to 84 percent. Beyond this time and at still lower humidities the permeability again increases resulting in a more uniform gradient of moisture throughout the whole tile.

These data indicate that the prediction of moisture concentration within a concrete mass depends on several variables, which are always present. Some of these are (a) continuing hydration depending on available water, temperature, and age (b) development of capillarity depending, upon batch composition, time of and rate of drying. The possible number of combinations of these variables may therefore result in many different properties of the concrete at any given time.

The drying of these tiles is being continued. Time rate of both weight loss and relative humidity tends to decrease as the relative humidity, of the exposed face, approaches that of the drying atmosphere.

The correlation of the relative humidity in the mid-cavity with the water loss for the whole specimen, illustrated in Figure 1, NBS Report 5855, continues as a straight line even though the time rates are considerably less.

2.3 Vacuum Processed Concrete

Test panels of vacuum processed concrete were subjected to the jet impingement test. The preparation of these six panels was described in NBS Report 5855. They were fabricated with concrete designed with portland cement and diabase aggregate.

The results are given in Table I, together with some data, not previously reported, for the same design concrete which was not evacuated.

The resistance to jet impingement of the evacuated concretes may be compared with that of similar concretes not evacuated given in Table I, NBS Report 5353 and Table I of this report.

The results of tests indicated that, for this type of concrete, the vacuum processed concrete developed equal or more resistance to jet impingement in less drying time. The two panels fabricated from the wet harsh mix P-D_1-5-1B and P-D_1-5-2B offered the best resistance to jet impingement but this concrete of specialized design might not develop adequate strength.

Efforts to demonstrate the presence of through pores in evacuated concrete have not been successful. Ink penetration tests and microscopic examination of sections saturated with methacrylate resin have not as yet revealed such pores.

2.4 Sources of Diabase

In the survey of sources of diabase two tons of this material was furnished this project by the New York Trap Rock Corporation. This aggregate is marketed in accordance with the New York State Specification. It was, therefore, necessary to rescreen and separate in accordance with the Bureau of Yards and Docks Specification. For comparative purposes the properties of both the New York and Virginia diabase appear in Table II.

Table I. Spalling Loss of Panels During Jet Impingement.

Concrete 1/	Panel	Drying Time 2/	Total Water at Time of Test 3/	Time of Exposure 4/	Spalling Loss Calculated From Weight 5/	Spalling Loss Calculated From Volume 6/
		days	%	minutes	cc	cc
$P\text{-}D_i\text{-}3$	1	21	7.70	5	44.8	58.00
	2	35	7.56	5	43.87	123.40
	3	49	7.68	5	84.11	211.70
$P\text{-}D_i\text{-}4$	1T	14	8.09	10	132.53	157.95
	2T	28	8.11	10	45.31	7/
	1B	14	7.78	10	91.47	103.47
	2B	28	7.65	5	91.19	103.15
$P\text{-}D_i\text{-}5$	1B	14	7.02	10	54.94	7/
	2B	28	6.61	10	45.86	7/

1/ The first letter; P=portland cement; The second letter: D_i=diabase aggregate; The numerals indicate the batch. The letters following the panel number indicate the method of evacuation T=top, B=bottom.

2/ Days stored at 73°F and 50 percent relative humidity sealed on all but one (18x18 inch) exposed face.

3/ Mixing water plus that absorbed during curing minus that evaporated during storage.

4/ Exposed to jet stream at 1200°F and velocity of 1200 feet per second.

5/ Calculated from weight loss.

6/ Determined by sand volume method.

7/ No visible loss.

Table II. Properties of Aggregates

	Virginia Deposit Centerville	New York Deposit Haverstaw
Absorption[1/]		
Coarse - - - - - - - -	0.6	1.18
Fine - - - - - - - -	1.54	1.70
Bulk Specific Gravity[1/]		
Coarse - - - - - - - -	2.96	2.85
Fine - - - - - - - -	2.87	2.78
Percent Loss in Los Angeles Abrasion Test - - - -	25.9	13.7
Ratio of Coarse-to-fine Aggregate - - - - - - -	65 to 35	same

Both aggregates were graded in accordance with the Bureau of Yards and Docks Specification.

[1/] These properties were determined on the same sizings as used in the concrete mix.

Figure 2 is a photomicrograph of a thin section of the New York diabase between crossed nicols. This may be compared with Figure 1 of NBS Report 4869 which is a similar photo of Virginia diabase.

Using this diabase from the New York district a concrete was designed, a batch mixed, and test specimens fabricated. For comparative purposes the properties of this concrete and one similarly designed but using Virginia diabase appear in Table III.

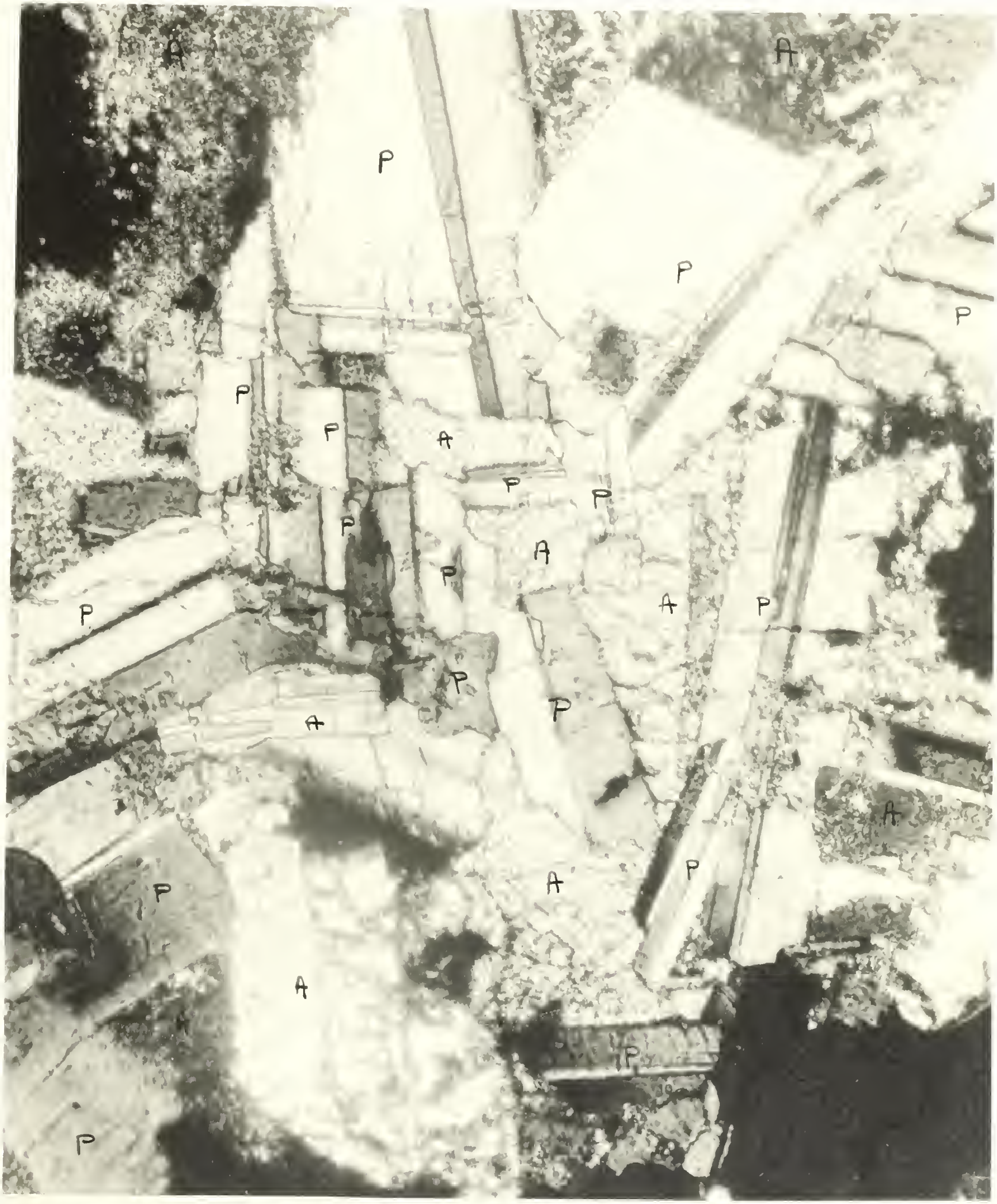

Figure 2. Photomicrograph of New York Diabase ([illegible]00X) (Crossed Nicols) Showing Plagioclase Feldspar (P); Altered Pyroxene (A), no Quartz Observed.

Table III. Properties of Fresh Concrete

	A[1]	B[2]
Proportions, by weight: cement to coarse and to fine aggregate - -	1:3.18:1.71	same
Cement content - - - - - - - - - - - -	7.31	7.16
Vinsol resin, by weight of cement - -	0.01	same
Water content, gal/yd^3 of concrete -	32.7	31.3
Air content, gravimetric method - - -	2.2	1.7
Slump, inches - - - - - - - - - - - -	2.25	1.0
Weight of fresh concrete, lb/ft^3 - -	161.44	158.50
Water cement ratio - - - - - - - - - -	0.40	0.39
Remarks - - - - - - - - - - - - - - -	harsh but easily placed	same

[1] A designed with Virginia diabase.

[2] B designed with New York diabase.

2.5 Miscellaneous

At the request of the Bureau of Yards and Docks staff, three and one-half tons of diabase aggregate (Centerville, Virginia deposite) was shipped to your laboratories at Port Hueneme, California. This aggregate is marketed in accordance with the size specification for Virginia State Highways. From this product, we selected the size fractions that would give the largest yield of aggregate sizes requested by Port Hueneme.

As a result of a conference with members of the technical staff, of a manufacturer of proprietary materials intended for use at high and fluctuating temperatures, four panels were submitted for jet impingement tests. Two of the four panels,

one organically bonded, the other with an inorganically bonded, were damaged during the test. The extent of the damage was comparable to that suffered by a diabase concrete panel. The remaining two showed no apparent damage. One of these had an inorganic bond and had been previously heated to 2300°F. The other, organically bonded, had been heated to 300°F.

3. CONFERENCE

A conference was held at this Bureau on June 25. The names of those attending were:

L. A. Palmer Melvin Herman	Bureau of Yards and Docks
S. Zerfoss W. L. Pendergast	National Bureau of Standards

The object of this conference was to discuss the proposal for the continuation of this project for the fiscal year of 1959. This proposal was submitted to the Chief of the Bureau of Yards and Docks, June 6, 1958. The research activities considered were,(1) limits of water content,(2) specifications for aggregate,(3) development of connecting pores,(4) relation of texture to explosive spalling,(5) relation of water content to relative humidity within concrete,(6) mechanism of water vapor transfer and, (7) performance of proprietary materials.

Literature

Topping Pavements with Calcium Aluminate Cement Concrete, by W. C. Hansen and W. W. Brandvold, J. Amer. Concrete Institute, May, 1958, No. 11, Vol. 29.

A study of the methods of placing a topping of calcium aluminate cement concrete on a portland cement concrete base to provide a surface for airfield pavements that would be resistant to the heat of jet and rocket engines.

Some Physical Properties of Concrete at High Temperatures, by Robert Philleo, J. Amer. Concrete Institute, No. 10, Vol. 29, April, 1958.

Experimental techniques are described and data are presented on the thermal expansion, density, and dynamic modulus of elasticity of concrete in the range 75 - 1500°F. Such information is necessary to evaluate stresses due to non-uniform heating which could result from a building fire or jet aircraft blast. The results indicate that weight loss due to loss of water is substantially complete at 800°F. At higher temperatures changes in weight are determined by the chemical nature of the aggregate. The coefficient of expansion increases above 800°F since expansion is no longer inhibited by drying shrinkage. At 1400°F the M/E is reduced to less than half in value at 75°F, the exact reduction depending on the extent to which hydration progressed at the time of exposure.

A Compilation of X-ray Powder Diffraction Data of Cement Minerals, by H. G. Midgley, Magazine of Concrete Research, March, 1957.

The identification of 30 minerals in high alumina and portland cement. A compilation of new and available data on X-ray powder diffraction of cement minerals.

Methods for Rating Concrete Waterproofing Materials, by F. Kocataskin and E. G. Swenson, ASTM Bulletin, April, 1958, No. 229.

In an attempt to develop reliable test methods for evaluating the effectiveness of concrete waterproofers, it was found that a combination of saturated and unsaturated permeability tests was necessary. The latter covering more than one humidity condition. The saturated permeability apparatus described might be used to advantage to indicate the initial permeability of concrete.

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major laboratories in Boulder, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside front cover.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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